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Measuring countries' environmental sustainability performance – A review and case study of Iceland

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ABSTRACT

Evaluating the environmental sustainability performance of a nation is complex. This paper considers the merits of environmental indices, and how effective they are when assessing the environmental sustainability of any nation. The simplicity and generic qualities of environmental indices currently necessitates a much broader analysis in order to evaluate any nation's genuine environmental sustainability credentials – ultimately the development of a synthetic Environmental Sustainability Index is required to fulfil this task. Using Iceland as a case study, this paper reviews the usefulness of four selected environmental indices (Environmental Vulnerability Index, Environmental Performance Index, Ecological Footprint and Happy Planet Index) for governance institutions when formulating reasoned responses to challenges. By adopting a holistic methodology, Iceland's environmental sustainability credentials are critically examined in this paper, with particular focus given to the impacts deriving from expanded renewable energy utilisation in recent years. Abundant geothermal and hydropower energy resources have been increasingly used to power heavy industry, particularly aluminium production. The wider health implications and long-term environmental sustainability consequences of renewable energy utilisation have not been analysed in depth within any of the indices. Socio-economic progress in Iceland has also been attained alongside the imposition of the highest ecological footprint of any nation in the world. As such, economic activities in Iceland have not occurred in accordance with commonly accepted notions of sustainable development, which is focused upon the reconciliation of economic, environmental and social objectives, together with recognition of current and future need across these domains.

Contents

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1. Introduction

Environmental sustainability is critical to the long-term flourishing capacity of individuals, societies and the natural world itself. Human consumption and economic development relies upon the sustainable use of environmental resources. Otherwise, environmental sustainability is vanquished. On a national and international scale, negative environmental impacts can affect the vitality of the land, oceans, freshwater systems, and atmosphere. The United Nations' Millennium Development Goals called for global efforts to ensure environmental sustainability, reversing the loss of essential global natural resources and maintaining biodiversity [1]. Major world resources, such as forests, not only provide the inputs for economic processes, but also play a critical role in mitigating anthropogenic climate change due to their carbon sequestration capacities, and availing mankind of many important non-monetary services such as water purification, waste decomposition and nutrient recycling [2].

The 1987 Bruntland Commission defined sustainable development as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ [3]. This definition sets in motion two key concepts: (1) ‘needs’ and the related constraint of technological capacity, and (2) the natural environment's scope to meet both current and future needs. Using Goodland's [4, p. 10] constraint-led depiction of environmental sustainability as concerning ‘the use of renewable and non-renewable resources on the source side, and pollution and waste assimilation on the sink side’, this paper considers how effectively selected environmental indices measure a country's performance across this domain. Taking Iceland as a case study due to its unique environment and varying ranking performance according to the selected indices, this paper considers two main research questions (1 and 2), and briefly uses this analysis to contemplate a third:

1) How to measure a country's environmental sustainability performance?
2) How environmentally sustainable is Iceland?
3) How can Iceland improve its environmental sustainability performance?

During the 25 years since the Bruntland definition was formed, the Nordic welfare model as applied in Iceland, with its maximisation of labour participation and strong social safety-net [5] is widely considered to be best-suited for delivering sustainable development [6]. In addition to providing high living standards and excellent levels of human well-being [7], the Nordic welfare model is often postulated as delivering environmental sustainability, particularly via the utilisation of renewable energy [8]. However, this understanding is generally based upon a flawed impression – it is claimed that Nordic nations are leaders in the field of environmental modernisation and political debate, not necessarily practice, and thus realisation at the national level is lacking [9]. To illustrate the imposition of environmental strain on a per capita basis, this paper will discuss how Iceland has the highest ecological footprint in the world. Consistently ranking towards the top of human welfare indices, this paper sets out examples of Icelandic economic activities that have led to the imposition of environmental strain with regards to the country's ecological footprint, actions often also resulting in increased greenhouse gas emissions (GHG). As a remote volcanic island in the North Atlantic, blessed with abundant renewable energy resources and a very small population (0.3 million), the Icelandic economy is heavily dependent upon fishing, heavy industry (particularly aluminium), and tourism [10] although other industries have been growing lately, e.g. software development. This paper explores Iceland's relationship with renewable energy, especially its increased utilisation to serve heavy industry and the effect that this is having on its environmental performance. In so doing, this paper exposes a common public misconception that the use of renewable energy automatically equates to environmentally sustainable practice [11].

The remainder of this paper includes a conceptual and methodological review (Section 2), results analysis (Section 3), discussion (Section 4) and conclusion (Section 5). The conceptual and methodological review responds to this paper's first research question, considering the nature of environmental sustainability and how it has been best defined, before articulating the merits of using environmental indices to measure national performance across this aspect of sustainable development. Each of the four selected environmental indices is critically examined to establish the extent to which they accord with definitions of environmental sustainability. In all cases, the indices have been developed to measure environmental sustainability components, and none on their own have clearly shown the path to economic development alongside less resource consumption and pollution, a pre-requisite of sustainable development. Even the most comprehensive of these, the environmental performance index (EPI), focuses mainly on the environment with scarce consideration of the interface between this domain and the economy. Instead, this paper highlights that the most significant contribution made by environmental indices is one of simplicity, facilitating an ease of understanding for policymakers and society, many of whom can be unfamiliar with environmental issues and concerns [12]. However, in their straightforwardness, environmental indices demonstrate a tendency to display generic qualities, and the performance outcomes discussed in this paper's analysis section – and responding to the second research question – often bear little or no relation to the specific issues relevant to a country, in this case Iceland. As a result of their lack of comprehensiveness, Iceland's ranking performance according to the selected indices varies considerably, and no index alone can provide a measure or evaluation of a country's environmental sustainability.

By analysing four indices together and closely examining overlooked environmental aspects, this paper shows that a more holistic depiction of Iceland's environmental sustainability performance can be established, and this approach could be applied when appraising other nations' environmental sustainability performance too. This paper's discussion session then articulates a range of measures that Iceland could undertake to not only improve their performance under each of the environmental indices, but their overall environmental sustainability credentials.

2. Conceptual and methodological approach

The assessment, measurement and evaluation of sustainable development components, including its environmental aspect, are

closely related concepts, but different in terms of their processes. When measuring environmental sustainability, environmental indices first identify appropriate variables for assessment, prior to the collation and analysis of suitable data. The most robust environmental sustainability indices will incorporate standards against which performance can be compared. This process aims to facilitate an ease of understanding for policy-makers, but the application of generic targets across nations can reduce the meaningfulness of such endeavours. This section therefore considers the nature of environmental sustainability itself via a literature review, and then discusses selected indices with respect to how effectively they capture the concept to transmit relevant information signals to policy-makers.

2.1. Environmental sustainability

The classical Bruntland definition of sustainable development uses a three pillars approach to express, in abstract terms, the relationship between economic activity, quality of life and the perpetuity of ecosystems and natural resources. A society devoid of functioning life-support systems cannot thrive; an absence of supportive social structures and institutions prevent economies from flourishing. Moreover, sustainable development has often been interpreted as social and economic development that should be environmentally sustainable [13]. In the period since the Bruntland definition was first published, it has slowly become accepted that environmental sustainability has its own merits [14].

Goodland [4, p. 3] asserts that environmental sustainability seeks to 'improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans'. This conceptualisation recognises that environmental sustainability concerns the placing of constraints on resource consumption, which is also a central tenet of the ecological economics framework of 'limits to growth'. In addition, Goodland [4, p. 4] also proceeds to describe environmental sustainability as the imposition of constraints on four major activities affecting the scale of the human economy: 'the use of renewable and non-renewable resources on the source side, and pollution and waste assimilation on the sink side'.

Moldan, Janouskova and Hak argue that the Organisation of Economic Co-operation and Development (OECD) further advance the concept of environmental sustainability within their environmental strategy for the first decade of the 21st century, published in 2001 [13]. The OECD's strategy [15, p. 6] defined four specific criteria for environmental sustainability:

1) Regeneration – renewable resources shall be used efficiently and their use shall not be permitted to exceed long-term rates of natural regeneration.
2) Substitutability – non-renewable resources shall be used efficiently and their use limited to levels which can be offset by substitution with renewable resources or other forms of capital.
3) Assimilation – releases of hazardous or polluting substances into the environment shall not exceed their waste assimilative capacity.
4) The avoidance of irreversibility.

The OECD used their four specific criteria for environmental sustainability as a means of contemplating five inter-related objectives for advancing environmental policies in a sustainable development context [15, p. 6]:

1) Maintaining ecosystem integrity via the efficient management of natural resources.
2) Decoupling of environmental pressures from economic growth.
3) Enhancing quality of life.
4) Improving global environmental interdependence by improving governance and co-operation.
5) Measuring progress, particularly using environmental indicators and indices.

The environmental sustainability concept can be further developed through the use of an ecosystem services perspective, as this reinforces the value pertaining to non-monetary ecological qualities and functions, all of which are necessary for the OECD's five inter-related objectives to be met. Daily discusses 'nature's services' to be comprised of a global life-support system (such as the climate system or hydrological cycle), goods provided by the geosphere (such as mineral resources), and open space (such as land on the planet's surface, plus the space above and below it) [16]. In meeting the OECD's five objectives for environmental sustainability, human well-being is maintained or advanced. On this basis, ecosystem services can be considered a fundamental component of human well-being. Moldan et al. therefore conclude that environmental sustainability may be defined as the maintenance of nature's services at a suitable level [13]. This requires ecosystem services on a local, national and international scale to be kept in a healthy state, and by definition requires governance systems to have a duty of care and regulatory impact on environmental infrastructure.

2.2. Indicators and indices as a measure of environmental sustainability

To provide a transparent and objective means of measuring and demonstrating the environmental sustainability of a country, it is often beneficial to use environmental indicators and indices [17]. There is no one set of national environmental indicators that is comparable to the standard set of measures used to measure economic performance [18]. In economic policy, countries are commonly compared on the basis of their gross domestic product (GDP) growth and performance. In the environmental field, the most comprehensive set of indicators is incorporated within the EPI, which strives but largely fails to provide an overarching depiction, capturing the environmental sustainability concept rather than its specific components, such as pollution, energy consumption and soil degradation. A similar lack of comprehensiveness can be observed within sustainable development indicators, with the resulting effect that economic activities undertaken in the name of 'sustainable development' often continue to threaten environmental integrity in a specific locality [19]. Furthermore, the subjective process of normalising and weighting indicators of environmental sustainability is consistently prone to a high degree of arbitrariness and lack of consideration as the consistency and meaningfulness of outcomes, reducing their relevance in terms of policy practice [20].

In theory, the use of environmental sustainability indices to measure sustainable development is an essential means of illustrating to policy-makers and general society the relationships and trade-offs among its three dimensions. Although not without their share of critics due to uncertainty as to how well they represent environmental sustainability in practice [19,20], environmental indicators and composite indices can be useful tools for assessing the condition of the environment and monitoring trends over time, as well as characterising conditions under which resource uses are sustainable [21].

Assessments of sustainability, particularly environmental sustainability, have four common features: (1) a subject focus on the relationship between human activity and nature; (2) orientation towards the long-term and an uncertain future; (3) normative foundation in the concept of justice, between humans of present and future generations as well as between humans and nature;

and (4) concern for economic efficiency in the allocation of goods and services, as well as their man-made substitutes and complements [22]. Capturing the full dynamics of environmental sustainability factors as discussed in Refs. [4,13,15,16], and presenting them in terms of easily interpretable measurement indicators is a challenging task. The United Nations [23, p. 2] asserts that environmental indices need to successfully capture the following four strands:

1) Impacts of economic activity on the environment (e.g. resource consumption, pollution emissions, waste management).
2) Effects of resource productivity on the economy (e.g. economic efficiency).
3) Impacts of environmental degradation on economic productivity (e.g. reduction in absorptive capacity, loss of forest cover).
4) Effects of environmental improvement on society (e.g. congestion costs [reduced], improvements in well-being, societal costs [reduced]).

Despite evident commonalities in the various definitions of environmental sustainability, there are no indicator sets or a composite index that satisfactorily and comprehensively measures the concept on a national and international scale. Parris and Kates set out three reasons why this is the case: (1) the ambiguous nature of sustainable development; (2) the plurality of purpose in characterising, and (3) measuring sustainable development; and confusion concerning terminology, appropriate data and methods of measurement [24]. Therefore, the range of indicators and indices needed to quantify any country's environmental sustainability credentials does not allow for a uniform, well-defined selection process, and thus expert judgement has been important. Table 1 outlines the four selected environmental indices used to analyse Iceland's performance in this paper.

Several other international indices were considered for evaluation in this paper. These included the living planet index, satisfaction with life index, human development index and sustainable society index. These were rejected for the following reasons:

– Environmental sustainability index: a composite index assessing 21 elements of environmental sustainability, however since 2005 it has been replaced by the more comprehensive EPI.
– Barometer of sustainability: includes all three of the sustainable development dimensions, but the limited scope of the environmental aspect (9 categories) and lack of a policy-to-target approach rendered the EPI a more comprehensive tool for review.
– Surplus biocapacity index: this index lists countries according to the balance or deficit between their EF and national biocapacity. Although the surplus or deficit in bio-capacity is an important criterion for evaluation and is considered in this paper, an international ranking list offers nothing further in terms of analytical value.

Table 1
Selected environmental indices.

Environmental Indices	Authors
Environmental vulnerability index (EVI)	South Pacific Applied Geoscience Commission and United Nations Environment Programme
Environmental performance index (EPI)	Yale University, Columbia University, World Economic Forum and Joint Research Centre of the European Commission
Ecological footprint (EF)	Global Footprint Network
Happy planet index (HPI)	New Economics Foundation

– Satisfaction with life index: assesses subjective well-being across nations relative to wealth, health and access to basic education. On the basis that it fails to include any form of ecological focus, the HPI was preferred.
– Human development index: although a comprehensive socio-economic metric broadly akin to the satisfaction with life index, it also lacks any consideration of environmental issues and thus was ignored in favour of the chosen indices.
– Living planet index: focuses specifically on the issue of biodiversity stocks and in a global context, thus lacking sufficient scope to assess environmental sustainability issues in a national context.

2.2.1. *Environmental vulnerability index*

The environmental vulnerability index (EVI) assesses the vulnerability of the physical environment at the country level by using a total of 50 environmental indicators: 32 measuring hazards, 8 quantifying resistance and 10 assessing damage [25]. Although there is no consensus as to the best method to quantify environmental vulnerability, Eakin and Luers state that any assessment should consider one or more exposure to risks, susceptibility to damage, capacity to recover, and outcomes [26]. The EVI broadly incorporates three of Eakin and Luers considerations – exposure to risks, susceptibility to damage and outcomes – but fails to address national recovering capacity or outcomes on anything other than an aggregate national basis.

Goodland's [4], p. 3 description of environmental sustainability as seeking to ‘improve human welfare by protecting the sources of raw materials’ resonates strongly with the overarching objectives of the EVI. The EVI strives to uncover broad strategic threats that might impact on the sources of raw materials key to the economic flourishing capacity of a nation. By offering an understanding of national environmental vulnerabilities, the EVI may facilitate the capacity for policymakers to accord with the first of the OECD's five objectives for advancing environmental policies – the maintenance of ecosystem integrity via the efficient management of natural resources. In so doing, governance can also contribute to the meeting of the OECD's third objective concerning the enhancement of quality of life.

The EVI strives to provide a rapid and standardised method for characterising environmental vulnerability in an overall sense and to identify issues pending consideration by governance institutions [25]. A weakness of the EVI concerns the term ‘vulnerability’, which is in itself imprecise and lacking a single definition, although Cutter articulates that the term is best described as referring to the potential for loss [27]. The vagueness of the ‘vulnerability’ definition renders it difficult for the EVI to delineate the environmental losses and damages that would be considered unacceptable. The outcome of vulnerability damage is described as ‘damage to the biological integrity or health of ecosystems, and therefore their ability to keep supporting humans’ [25, p. 4], however it is not specified how much loss equates to an unacceptable outcome, as perhaps this would necessitate a culturally-specific engagement with the diverse values of the environment to a nation. As the EVI does not have the comprehensive scope needed to measure social loss, it is unable on its own to offer a common basis on which decision-makers can compare information about their environment with information concerning their development [28].

Causal relationships among EVI indicators are not expressed [29]. The EVI fails to directly address the socio-economic aspects expressed by the third and fourth of the United Nations' strands for environmental assessment. The EVI is furthermore unable to reflect strategic national responses that have already been undertaken in response to environmental vulnerability issues. The complex task of constructing a national-scale environmental index

that enables international comparisons and decision-taking relevance for policymakers has led to abstraction within the EVI, diluting its overall meaningfulness. Thus the EVI's significance in terms of this paper is as a useful starting point for further discussion concerning the potential vulnerabilities and risks to the environment faced by any country – in this case Iceland.

2.2.2. Environmental performance index

The environmental performance index (EPI) (superseding the environmental sustainability index since 2005) uses 25 indicators across 10 policy categories to attempt to quantify the environmental performance of countries relative to each other [30]. The EPI brackets indicators according to two core objectives: reducing stresses to environmental health (environmental health objective; worth 30% of the overall weighting); and protecting ecosystems and natural resources (ecosystem vitality objective; worth 70% of the overall weighting). Each indicator is linked to long-term public health or ecosystem targets which are common to all countries, such as the facilitation of 100% access to sanitation. For each country a proximity-to-target value is calculated using the difference between actual performance and the policy target. The targets are the same for all countries and are derived from four sources: (1) treaties or other internationally agreed goals; (2) standards set by international organisations; (3) leading national regulatory requirements; and (4) expert judgement based upon the prevailing scientific consensus [30].

The application of generic policy targets to all nations does not reflect the national environmental challenges faced by politicians; however this approach does accord with Goodland's recognition that environmental sustainability concerns the placing of constraints on resource consumption [4]. The EPI's suite of indicators incorporates three of the OECD's four specific criteria for environmental sustainability, with threshold irreversibility not incorporated [15]:

- The regenerative capacity of environments is assessed by the use of indicators related to forest cover change, coastal shelf fishing pressure and fishing stocks overexploited.
- The substitutability of non-renewable resources is quantified via the use of a variety of indicators related to subjects such as biome protection, marine protection and forest loss.
- The assimilative capacity of environments is addressed through indicators related to particulate matter pollution, sulphur dioxide emissions, carbon dioxide emissions and pesticide regulation.

The comprehensive scope of the EPI's indicators also corresponds with the OECD's five objectives for advancing environmental policies. In particular, the use of a proximity-to-target approach is very useful for measuring national progress over time. This process has been further improved via the release of the EPI's 2012 report, which incorporates a ‘Pilot Trend EPI’ and ranks countries based on their environmental performance changes over a decade. By quantifying not only environmental outcomes against policy targets for a specific year, but also progress over a decade, the EPI partially responds to Heink and Kowarik's yearning for an assessment tool assessing the conditions of the environment and trends over time. The extent to which the EPI actually characterises the conditions under which resource uses are sustainable in a country depends on the applicability of the policy targets and scope of the indicator set [29]. The EPI's inbuilt political dimension garners the potential for the metric to become a useful reference tool for national governance institutions when setting economic and environmental policies. However, the plurality of purpose in measuring environmental sustainability ensures that the EPI's main benefit appears to be a derived improvement in the empirical basis for instigating long-term environmental protection measures and the facilitation of improved analytical assessments.

2.2.3. Ecological footprint

The ecological footprint (EF) is calculated by the global footprint network and measures the total amount of goods and services consumed by a country's inhabitants on a per capita basis, as well as the amount of waste assimilated and the area of vegetated land required to sequester all CO_2 emissions and those embodied in products consumed [31,32]. The EF is a measurement of the burden a country places on its productive land and marine resources, including foreign land used in the production of imports. Due to its focus on consumption, the EF accords well with Goodland's definition of environmental sustainability, which emphasises the importance of protecting the sources of the raw materials used to satisfy human needs and waste sink constraints [4]. The EF's headline statistic may act as a clarion call for national governments to heed two of the OECD's five objectives for advancing environmental policies – maintaining ecosystem integrity via the efficient management of natural resources and decoupling environmental pressures from economic growth.

Wiedmann and Barrett conclude that the EF, as an environmental sustainability index, has three main strengths [33]. The first strength is (1) its ability to condense the size of human pressure on different types of biodiversity into a single number; (2) the possibility to provide a sense of overconsumption, and (3) the opportunity to communicate results to a wide audience [33]. The second strength of Wiedmann and Barrett's analysis refers to the merits of only a limited data snapshot, which enables a performance comparison between nations [33].

However, the EF statistic on its own is unable to provide the information needed to conduct policy reviews by national governance institutions. Its statistic is unable to provide any answer to the question of how long over-consumption will occur for, or the full environmental implications of doing so, such as the relationship between a high EF and climate change effects. In essence, the EF lacks an explicit ‘ecological’ focus. The EF is a comparison between aggregate consumption and resources across a nation, but it lacks information associated to environmental sustainability, excluding issues such as soil loss, consumption of freshwater supplies and the loss of forest cover [34]. Moreover, Nourry considers the absence of irreversibility and threshold considerations within the EF methodology to be a fundamental weakness of the metric [35].

A major weakness of the EF concerns its failure to recognise one of the most important environmental sustainability issues: land degradation [34,36]. The EF does not account for the environmental implications stemming from land use practices, and thus its statistic is predominantly an indication of strain rather than a reference guide for forming environmental policy responses. Land that has suffered degradation can either not be used, or it functions with vastly decreased efficiency [37]. Degraded land leads to a need for new sources. It is therefore inferred that the inefficient use of farming land may be a more sustainable approach than the on-going degradation of land sources. As such, a larger EF might be more sustainable than a smaller one, but as it is merely a static variable, it is unable to address this issue.

2.2.4. Happy planet index

The happy planet index (HPI) represents a ratio of human well-being to environmental impact. It is an assessment of the ecological efficiency of delivering a certain level of subjective human well-being. The HPI combines two indicators: first, how long and happy people live in a country via the medium of ‘Happy Life Years’; and second, how many resources citizens consume as

measured by the EF. The concept of 'Happy Life Years' merges civil registration data on longevity with survey data on average life satisfaction in countries [38]. The HPI was developed following recognition that the gross domestic product (GDP) per capita statistic was deeply flawed as a measurement of national human well-being. GDP fails to account for the environmental costs of economic activity, growing rather than reducing in the face of negative externalities such as air pollution, or the loss of natural capital [39]. The country that does this best under the HPI is considered to be the one that inflicts least infringements upon the opportunities for others and future generations to do the same. This is in accordance with the essential tenet of the Bruntland definition of sustainable development, which demands 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' [3, p. 24]. The HPI is an easily understandable metric and performance can be compared across nations.

Enhancing quality of life represents the third of the OECD's five objectives for advancing environmental policies. The HPI infers that the delivery of greater levels of average national well-being can occur via the imposition of a reduced burden on productive land resources. The crafting of environmental policies to enhance national well-being is central to the success of any governmental action aimed at mitigating environmental impact [40]. However, the HPI does not permit the identification of relationships and trade-offs between environmental strain, as measured by the EF, and subjective human well-being. The static EF statistic is in itself an inadequate tool for forming environmental policy responses. Meanwhile subjective well-being is dependent on many policies and factors beyond the remit of the environmental policy arena, such as quality of healthcare and education. Indeed, Johns and Oremerod conclude that the range of variables leading to subjective human well-being is so numerous that the challenge of identifying environmental causes is insurmountable [41].

3. Results

This paper analyses the most recent data available for the four environmental sustainability indices – EVI, EPI, EF and HPI – for the purpose of demonstrating how a country's environmental sustainability performance can be evaluated. The analysis comprises (1) the results from the indices, and (2) an examination of broader environmental sustainability criteria relevant to Iceland. Table 2 identifies the world ranking for Iceland according to the respective index. In the case of the EVI, EPI and HPI indices, a low number ranking is considered to represent 'better' environmental performance than a higher number ranking. The opposite is the case for the EF index. Note that Iceland was not ranked within the living planet report. An EF assessment for Iceland was undertaken by Jóhannesson [42] in accordance with the Global Footprint Network methodology. A higher EF is calculated for Iceland than any other country published within the official ranking list.

3.1. Environmental vulnerability index

The EVI was calculated on a one-off basis in 2005. As discussed, rather than assessing solutions and policy-responses to environmental stresses, this index is a useful starting point for briefly identifying critical issues and threats. These issues are of significant importance when considering the results in the other environmental indices, which to some extent do reflect strategic policy-responses or expose economic practices that might impinge on the sustainability of a threatened national environment.

Table 2
Comparative environmental index rankings for Iceland.

EVI (2005)	EPI (2012)	EF (2010)	HPI (2012)
112th/234	13th/132	1st/154	88th/151

Iceland's overall index score was 298, equating to 'vulnerable' status. The issues of greatest environmental vulnerability were assessed as being the following:

- **High winds** – a high number of days where the wind speed is at least 20% greater than the 30 years monthly mean.
- **Wet periods** – assessed by the amount of rainfall months (mm) at least 20% in excess of the 30 years monthly mean.
- **Volcanoes** – high risk of erupting volcanoes relative to land area size.
- **Vegetation cover** – low percentage of natural and regrowth vegetation cover remaining.
- **Degradation** – high percentage of land area either severely or very severely degraded.
- **Productivity overfishing** – low average productivity to fisheries catch ratio.

Iceland is identified as having a considerable vulnerability to land degradation and has already lost most of its vegetative land cover, an issue that has relevance within the EF index and greatly limits Iceland's current capacity to sequester greenhouse gas emissions. Erosion and desertification have been serious problems in Iceland through much of its post-settlement history [43]. In the period after settlement, widespread deforestation occurred, and after the remaining woods and thickets were lost, the remaining vegetative cover was generally unable to withstand the pressure and eroded away [43]. Many lowland areas in Iceland have become barren or sparsely vegetated, while highland areas are almost totally devoid of soil and plant cover [44]. This consideration ensures that the management of Icelandic grazing practices needs to reflect the tolerance levels of the land. Adopting further re-vegetative techniques would help to increase storage of greenhouse gases, reduce vulnerability to further land degradation and contribute to the functioning of important ecosystem services, such as water filtration.

The EVI depicts Iceland as a nation over-exploiting fish stocks in its waters. The term 'productivity overfishing' is defined by the EVI as 'fishing beyond the capacity of the environment to replenish stocks through primary production and biomass transfer' [25, p. 34]. A small productivity to catch ratio is considered by the EVI to equate to an environmental vulnerability. The indicator uses food and agricultural organisation data from 1993 to 1998, a period that is too long ago to represent an accurate assessment of Iceland's current marine resilience. As well as using old data for certain issues, the EVI fails to discuss the efficacy of strategic responses to vulnerabilities (e.g. Iceland's total allowable catch system) that have already been undertaken by governance institutions.

3.2. Environmental performance index

The overall index score for the EPI is relevant only so far as it reveals different standards of environmental performance relative to set policy targets. Iceland ranks 13th according to the 2012 list of nations – a reduction of 12 places from top-billing in 2010 – mainly due to performance improvements by other countries [45]. Although Iceland's overall score has shown positive trends between 2010 and 2012, the country's 'pilot trend' (again calculated from 2010 to 2012) scores for the policy categories of fisheries and water resources (ecosystem effects) show a downward path, with reductions of 13.0 (out of 100) and 17.9 (out of 100) respectively [45]. Along with improved performance by other

Table 3
Description of Iceland's environmental health objective performance [45].

Policy category	Indicator	Policy-to-target requirement
Air (effects on human health)	Indoor air pollution	This indicator uses household survey data to determine the percentage of a population using solid fuels (wood or biomass) to cook in the home. The target for all nations, based upon expert opinion, is for 100% of homes to be using alternative and cleaner alternatives to solid fuels
	Particulate matter	This indicator models 3-year moving averages for PM 2.5 (particulate matter 2.5 μm in diameter and less) concentrations from 2001 to 2010 to generate global distributions of PM 2.5 concentrations. Population weighted averages of the distributions are used to provide national estimates of annual average exposure in micrograms per cubic metre (μg/m³). National performance is compared against a target of 10 μg/m³ for PM 2.5 concentrations
Environmental burden of disease	Child mortality	This indicator extrapolates UN Populations Division data, obtaining the probability of a child whom is still being alive at his/her first birthday, dying prior to their fifth birthday. The target probability for all nations is 0.0007, which represents the fifth percentile of 2000–2010 data
Water (effects on human health)	Access to drinking water	This indicator by percentage of national access to 'improved' drinking water sources, defined as including piped water into a dwelling, public tap/standpoint, borehole, well, protected spring or rainwater collection system. The target is 100% for all nations
	Access to sanitation	The indicator is assessed as the number of people using 'improved' sanitation facilities in relation to the total population, expressed as a percentage. Improved sanitation facilities are defined as connection to a public sewer connection, septic system, pour-flush latrine or ventilated pit latrine. Estimates are based on data from nationally representative household surveys and censuses. The target is 100% for all nations

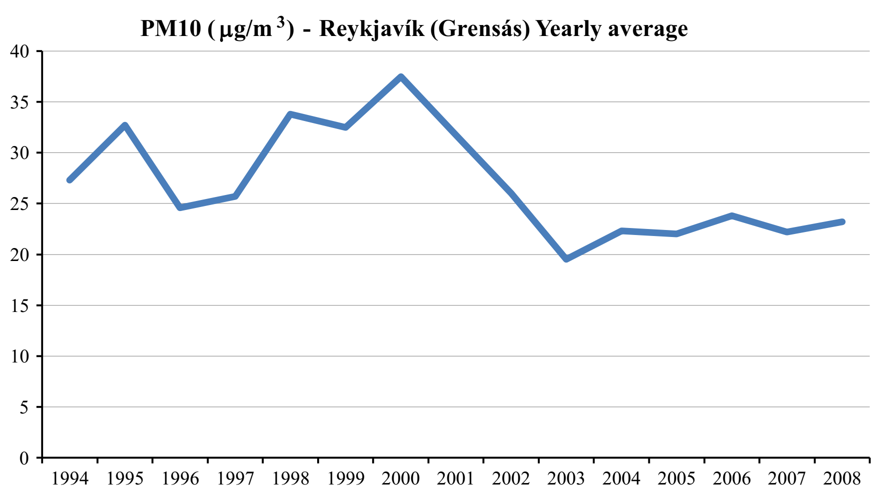

Fig. 1. Average annual PM10 concentrations in Reykjavik, Iceland.

nations, these are the most significant variables behind Iceland's ranking decline. In addition, the absence of recent (2008 onwards) or any Icelandic data for key indicators such as fish stocks overexploited, sulphur dioxide (SO_2) per capita, SO_2 per unit of GDP and particulate matter emissions, also suggests that the determination of the 2010 and 2012 ranking placements is influenced considerably by data availability.

Based upon the EPI's environmental health objective (weighted as 30% of the total score), Iceland currently ranks joint first among all nations, with a sub-index score of 100 [45]. This means that Iceland fully meets each of the policy-to-target requirements for the policy categories of air (effects on human health), environmental burden of disease and water (effects on human health). Table 3 describes the criteria that Iceland has been assessed against within the environmental health objective.

Although no Icelandic homes use wood fuel and thus the country scores well under the indoor air pollution criteria, other domestic studies have demonstrated unsafe levels of carbon dioxide and particulate matter emissions. Hellsing's [46] evaluation of indoor air quality in Icelandic schools uncovered mean levels of CO_2 across 74 classrooms of 1510 ppm, and significantly above the recommended maximum limit value of 1000 ppm. In approximately 87% of the schools mean CO_2 levels lay above the recommended maximum limit.

The majority of the EPI's environmental health objectives have very limited applicability to a country such as Iceland, indeed any highly developed economic nation, and thus the use of the term 'improved' in the access to water and sanitation indicators is essentially an irrelevance. The issues of access to drinking water, sanitation provision, and child mortality are almost exclusively concerns of the developing world. Thus Iceland's score of 100 in these indicators is purely indicative of a certain degree of economic development and satisfactory welfare provision, rather than environmental sustainability per se.

The remaining environmental health objective indicator concerning particulate matter (PM) concentrations has more relevance to Iceland's situation. According to the EPI's 2012 report, Iceland has PM 2.5 concentrations of less than 10 μg/m³ on all occasions [45]. However, this outcome is a default entry due to the absence of any data and does not suggest that particulate matter concentrations are largely an irrelevance in Iceland. On the contrary, Icelandic data for PM 10 concentrations taken at the Grensás traffic station in Reykjavík reveal patterns well beyond the World Health Organisation's limiting value for the protection of human health of 20 μg/m³. Fig. 1 describes annual average PM 10 concentrations in Reykjavík in the period from 1994 to 2011, which are slowly declining over time, but almost all remain above the safe 20 μg/m³ mark. These readings are of particular concern in

Iceland as approximately two-thirds of the national population reside in Reykjavík and Greater Reykjavík area. Particulate matter concentrations have been shown to contribute to acute lower respiratory infections and other diseases such as cancer [47]. It should also be noted that the data in Fig. 1 is based upon yearly averages – one-off hourly readings in excess of 100 μg/m³ have been recorded [48].

In addition, the EPI assesses only health impacts from indoor cooking sources and external concentrations of particulate matter. Other sources of air pollution have historically been relevant to the Icelandic situation, e.g. nitrogen oxide (NO_x), with than half of the NO_x emission comes from fishing and one fourth from transport [49] and, more recently, hydrogen sulphide (H_2S), emissions that are explored by the EPI within their environmental vitality objective components.

For the ecosystem vitality objective, Iceland achieves an overall sub-index score of 51.8 and does not attain 100 in any of the policy categories of agriculture, air (ecosystem effects), biodiversity and habitat, climate change, fisheries, forests, and water resources (ecosystem effects). Iceland attains a score of 11 out of 100 for the policy target of air (ecosystem effects). This policy objective is calculated with reference to two indicators – SO_2 emissions per capita and SO_2 emissions per $ of GDP. Both indicators refer to total SO_2 equivalent emissions, which equate to the sum output of all combusted fuels containing sulphur. Country performance is assessed in comparison to an ideal target of zero SO_2 equivalent emissions for both of these indicators. Emissions of SO_2 generally occur when fuel containing sulphur is combusted. The gas is a pollutant, not only acting as a contributory agent to acid deposition in soils and watercourses, but also stimulating potentially negative implications for human health, assisting in the formation of particulate matter in the atmosphere and thus potentially aggravating breathing conditions such as asthma [50].

The annual average PM 10 readings for Reykjavík of greater than 20 μg/m³ may be sustained, at least in part, through vehicular pollution and specific weather conditions, such as dust storms [51]. A recent study of H_2S and PM 10 concentrations in Reykjavík and the dispensing of anti-asthma drugs was undertaken by Carlsen et al. [52]. Their study found that there was a correlation between one-hour peaks in traffic pollutants, and subsequent (3–5 days) increases in the number of adults filing prescriptions for asthma medications.

Virtually all European nations have been reducing their sulphur oxide emissions (SO_x) in the period from 1990 to 2010 through a combination of fuel switching, improved and more energy efficient industry processes and the installation of flue gas desulphurisation equipment [53]. This is in contrast to Iceland, where SO_x emissions have risen by 255% over the same time span [53]. These emissions mostly stem from geothermal energy production [53]. Analysis of Iceland's SO_2 equivalent emissions reveals a similar upward trend to SO_x. Geothermal power plants emit sulphur in the form of hydrogen sulphide (H_2S). When calculated as the standard unit of SO_2 equivalent emissions, H_2S emissions have increased by 333% in the period from 1990 to 2010 [54]. The expansion in SO_2 equivalent emissions is a result of a 15-fold expansion in electricity production since 1990 from Icelandic geothermal power plants [54]. The vast majority of total SO_x emissions are derived from the energy production sector, however, emissions from industrial processes, which are dominated by energy-intensive aluminium production, have risen by 238% in the period 1990–2010 [54].

There are environmental sustainability implications deriving from the Icelandic growth in SO_2 equivalent and SO_x emissions. Of particular concern are the increases in the concentration of H_2S on average across Iceland, and this problem is particularly acute in the capital city of Reykjavík. The World Health Organisation recommends maximum H_2S concentrations of 150 $\mu g/m^3$ over a given 24-h period to ensure the absence of acceptable risks that can cause adverse health effects to humans, such as acute eye irritation, dizziness, severe breathing difficulties and migraine headaches [55]. The European Environment Agency reported that concentrations of H_2S in the Reykjavík city area are a concern, with the highest 24-h reading being 170 $\mu g/m^3$ [56], 13.3% over the WHO's maximum guideline. Instances of 30 min average readings of greater than 150 $\mu g/m^3$ were found to be approximately one per month during studies in Reykjavik between 2007 and 2009 [57].

In other policy categories within the EPI's environmental vitality objective, Iceland scores 14 and 36.5 out of 100 for fisheries and agriculture respectively. Both policy categories are assessed using two indicators – coastal shelf fishing pressure and fish stocks overexploited for fisheries; agricultural subsidies and pesticide regulation for agriculture.

The coastal shelf fishing pressure indicator is assessed by calculating the ratio of the total catch from trawling and dredging gears divided by the exclusive economic zone (EEZ) area for a country. The fish stocks overexploited indicator is calculated as the fraction of species that are fished in a nation's EEZ that are deemed overexploited. Iceland has historically overexploited its trawled fish stocks – in 1975 foreign fleets were catching over 100,000 t of cod annually from the Icelandic stock [58]. Following the imposition of Iceland's EEZ in 1976, evidence was emerging that the most valuable fish stocks were being overexploited [59]. In 1984, a system of individual transferable quotas (ITQs) was introduced in the demersal fisheries, although with limited transfer rights. Each vessel received a fraction of the total allowable catch (TAC). Until 1990 the system was poorly managed and actual catches were far beyond the TACs. In 1990, the Icelandic Government made a concerted effort to limit total catches and an ITQ system was established for most of the commercial fisheries [58]. The fisheries management system, incorporating a TAC for each stock and use of ITQs, and the enforcement of the system, has been in steady development in the period since. The aim of the system is to re-establish the sustainability of fish stocks, based on scientific assessments and advice in accordance with international criteria, while maintaining the economic benefits for the sector.

Despite the introduction of the TAC and ITQs for all stocks, this has not translated into a high score (14 out of 100) according to the relevant EPI indicators. The nation's poor performance in this component of the EPI is only partly due to the very stringent political target set, which demands that nations source no more than 0.000016 t per square kilometre (EEZ) of trawled fish stocks and, additionally, the target for the fraction of fish stocks overexploited is set at zero. Both of these indicator targets are challenging for a nation such as Iceland, where fishing is central to the economy. Biological outcomes under the ITQ and TAC system currently appear to be mixed [60]. Overall the declining trend for most Icelandic fish stocks has been halted, fishing mortality has decreased and some individual stocks (e.g. herring and haddock) have recovered well, however cod stock levels have stayed low despite reductions in the TAC [60].

The score of 36.5 for the agriculture policy category is almost entirely explained by an indicator total of zero for 'agricultural subsidies'. This indicator is assessed using nominal rate of assistance data from the World Development Report (2008), and seeks to evaluate the magnitude of subsidies in order to assess the degree of environmental pressure they exert. The NRA is defined as the price of a good in the domestic market (plus any direct output subsidy) less its price at the border, expressed as a percentage of the border price [45]. The target percentage for all nations is zero. Unlike the European Union's common agricultural policy and its subsidies to farmers, Icelandic subsidies remain integral to production levels and Icelandic farmers are protected from imported goods by very high import duties on staple foods [61].

In the policy category of forests, Iceland's EPI score is 98.1 out of 100. In terms of the EPI, a relatively recent strategic shift towards afforestation leads to a misleading portrayal of Iceland's sustainability credentials in the forestry sector. Iceland's very high score is deceptive as the three forestry indicators – loss, cover change and growing stock change – all apply a base year of 2000. When Iceland was first settled, in the 9th century, approximately 25–40% of the total land area was covered by forests and woodland [62]. The forest was almost entirely lost as a result of climatic cooling and the need for land to graze sheep. Deforestation continued until the mid-20th century. Afforestation did not commence until 1969 [63] and Iceland's long-term goal, as set out in the Regional Afforestation Projects Act of 2006, is to increase forest cover to 5% of total land area [62].

Although the EPI successfully captures Iceland's near 100% use of renewable electricity, there are important environmental sustainability criteria not covered by the range of indicators. For instance, there are no indicators addressing the issues of soil degradation and waste management practices. One of the most pressing environmental challenges facing Iceland is the loss of vegetation by wind erosion. Soil erosion in Iceland is the most severe in Europe and has been progressing for the past 1200 years [44]. The challenge for Iceland is to re-vegetate sites and advance environmental sustainability. Soil conservation and restoration can play an important role in meeting the objectives of the United Nations Framework on Climate Change (UNFCC) and Iceland's greenhouse gas emissions targets as set out in the Kyoto protocol. CO_2, the main atmospheric greenhouse gas, is converted to organic matter by plant materials. Due to land degradation, it is estimated that up to 1.8 billion tonnes of CO_2 has been lost from and vegetation since the time of human settlement [64]. As the Kyoto protocol permits nations to use the conversion of CO_2 to organic matter as a means of meeting national emissions targets, a focus on re-vegetation has the capacity to considerably improve Iceland's environmental sustainability performance. Unlike most other countries, re-vegetation is a sector offering the biggest possible mitigation gain for Iceland but possible gains in electricity generation and heating are very small [65].

Waste management continues to be a major issue in Iceland, particularly within the capital city of Reykjavík. In 1995, the total waste generation for Iceland was 397,000 t [66]. This increased to 690,000 t (73.8%) in 2008, before then reducing in the aftermath of a financial crisis and more effective regulation (for example, the RR-SKIL scheme concerning the treatment of electronic waste was introduced in 2008) to 524,000 t in 2011 [66]. The recent introduction of more efficient waste management techniques has led to Icelandic rates of recycling (excluding composting) increasing from 11.8% to 55.7% between 1995 and 2011 [66]. Recyclable waste continues to be exported to recycling facilities in Europe, increasing greenhouse gas emissions during its transportation. There remains the potential for Iceland to further improve the sustainability of their waste management, increasing rates of recycling and composting, recovering energy from waste and reducing the total amount of waste sent to landfill sites.

3.3. *Ecological footprint*

The global footprint network (GFN) used data from 2007 to calculate the EF for the majority of the world's countries. Although Iceland's EF was not calculated during the GFN's study, a subsequent assessment was undertaken at the University of Iceland, using the same methodology, and it revealed that the country's EF was 56.0 ha per capita compared to bio-capacity of 21.7 ha per person [42]. An adapted methodology, which attempted to overlook methodological flaws concerning the treatment of Iceland's fishing grounds and their respective productivity, discovered that the country still had an EF of 12.7 ha per capita (ignoring totally the contribution from Iceland's fishing grounds), again higher than all other nations in the world and well beyond the nation's bio-capacity (again excluding fishing grounds) of 4.4 ha per capita [42]. The 8.3 ha per capita difference between Iceland's corrected EF and its bio-capacity represents a state of 'overshoot' or unsustainability. 'Overshoot' occurs when the demands on a national ecosystem exceeds its regenerative capacity, with the consequence being smaller stocks of land types such as forests or fisheries into the future.

Out of the total EF of 12.7 ha per capita, 11.3 (89%) were comprised of energy land (carbon offset from forests), with contributions from other land types of farmland (0.29), pasture (0.1), forest (0.54), and construction (0.50) very insignificant contributors to the total [42]. For many countries, the carbon footprint is the most significant contributor to the EF. However, in the case of Iceland, its carbon footprint exceeds the second highest overall EF in the world, a figure of 9.46 ha per capita in the United Arab Emirates [31] CO_2 emissions are the only waste product included in the National Footprint Accounts which form the backdrop to the EF calculation. On the demand side, the Carbon Footprint is calculated as the total amount of forest land required to absorb a nation's CO_2 emissions. Under the EF's calculation methodology, a nation's CO_2 emissions are domestic demand-based (thus excluding emissions stemming from exported goods), and in Iceland they are dominated by imports of fossil fuel products, food and machinery.

With regards to the full total (including exports), in 2010 Iceland emitted 3409 Gg of CO_2 emissions, excluding sequestration [65], a figure equating to 75% of total greenhouse gas emissions (GHG) from the country. Out of Iceland's total CO_2 emissions in 2010, 46.3% (1579 Gg) were sourced from metal production [65]. In comparison, in 1990, only 15.8% (341 Gg) of total CO_2 emissions stemmed from this source [65]. Total CO_2 emissions in 1990 of 2154 Gg were 1255 Gg less than in 2010, a difference that almost exactly matches the increase in emissions from metal production over this period. The main driver behind increased CO_2 emissions from industrial processes has been an expanded metal production sector, particularly involving aluminium, almost all of which is then exported. In 1990, only 87,839 t of aluminium were produced in a single plant; by 2010, 818,859 t of aluminium output derived from three plants [49], an 832% increase. In the period since 2005, during which the 690 MW Kárahnjúkar hydropower plant was completed and Alcoa's 4600 Gwh aluminium plant at nearby Fjardaál operationalized, Iceland's CO_2 emissions from industrial processes increased to 1589 Gg from 838 Gg, or 90% in proportional terms [54]. Although an insignificant contributor (5% of the 2010 total) to total CO_2 emissions, emissions from geothermal sources increased by 63% in the 2005–2010 period [54].

Iceland's CO_2 emissions from road transport have increased by 55% in the period 1990–2010 [67]. Iceland has the fifth highest vehicular ownership per capita in the world [68]. The increase in emissions is largely due to an increase in the number of cars per capita, more mileage driven and a tendency for Icelanders to buy larger and less fuel-efficient vehicles, with population growth of 24% over this period a less significant driver [54]. These factors, as well as a burgeoning tourism industry and ageing car fleet, have been responsible for a 100% increase in the demand for oil used by Iceland cars in the period 1982–2010 [69].

Although not captured by the EF, it is beneficial to examine the relationship between Iceland's metal production sector and overall GHG emissions. Table 4 examines Iceland's total GHG and provides a breakdown of sources from the respective sectors.

In the period from 1990 to 2010, Iceland's total GHG emissions increased by 30% from 3501 to 4542 Gg CO_2 equivalent [54]. The contribution sourced from industrial processes decreased from

Table 4
Greenhouse gas emissions by source in Iceland (2010) and excluding sequestration [67].

Component	CO_2 equivalent (Gg)	Percentage of total (%)
Fuel combustion	1674	36.9
Industrial processes	1810	39.9
Solvent and other product use	6	0.1
Agriculture	646	14.2
Waste	214	4.7
Geothermal power plants	193	4.2
Total	**4542**	**100.0**

25% in 1990 to less than 20% between 1992 and 1997, but has since risen to 40% in 2010 [54]. Indeed, of the 1810 thousand metric tonnes of GHG deriving from industrial processes, 95.3% were sourced from metal production [67].

The main energy source for Iceland's three aluminium plants is electricity generated from renewable sources: geothermal and hydro-power. Producing aluminium is an extremely energy intensive process, with this industry responsible for 71% of national electricity consumption in 2011 [69]. As GHG emissions accrue independently of the size of a country's population, industrial processes associated with Iceland's expanded aluminium industry are largely responsible for Iceland's per capita CO_2 emissions from the consumption of energy of 10.6 metric tonnes per person in 2010 [70], a figure higher than all of the other Nordic countries. Iceland has energy intensity of over triple the Nordic average [71], and this is entirely due to the predominance of the aluminium sector.

The Icelandic economy also remains heavily reliant on the fishing sector, marine products comprising 42.4% of Iceland's exports in 2012 [72]. Although still responsible for 15.7% of Iceland's CO_2 emissions in 2010 [67], the fishing fleet have installed energy efficient techniques, lowering emissions by 35.4% in the period from 1996 to 2010, however a shift to the use of renewable fuels has thus far been considered too costly. Rising global energy prices increase the likelihood of a shift to the use of more sustainable fuels in the future. The combustion of fossil fuels by fishing vessels can also have considerable environmental impacts, particularly negative effects on biodiversity via increased ecosystem toxicity. Positive environmental improvements have been made in some of Iceland's energy intensive fish meal plants, more of which are now fuelled by renewably-generated electricity rather than fossil fuel combustion.

Although the EF methodology has been shown to be flawed in its treatments of Iceland's fishing grounds [42], the final statistic is unable to reveal on its own the full environmental sustainability implications pertaining to countries, such as Iceland, that place a considerable burden on productive land and marine resources, beyond bio-capacity. It is important to note that Iceland is currently one of the least-equipped nations to sequester its per capita CO_2 emissions via forests, or indeed any other form of absorptive vegetation [44], although it has considerable potential for improvement in this area. As was the case with the EPI, the pressing issues of soil degradation, widespread desertification and limited programmes of relatively recent afforestation are all overlooked within these environmental indices. The risk is that to maintain a current course of economic action requires more of the same – more natural resources – and the EF data for Iceland asserts that the nation is already living well beyond bio-capacity.

The EF is merely an indicator of environmental strain, as opposed to an identifier of the background conundrums that must be addressed in order for a country to reduce its impact on productive land and marine resources. Goodland [4, p. 3] stated that environmental sustainability 'seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans'. In addition, the OECD's 2001 criteria for environmental sustainability included the 'decoupling of environmental pressures from economic growth' [15]. The emphasis here is one of resource consumption constraints and the need for recognition of environmental vulnerabilities.

3.4. Happy planet index

The HPI is the ratio of happy life years to a nations EF. Table 5 summarises Icelandic performance according to the HPI's data.

Iceland's average subjective well-being score of 6.9 lags behind the Nordic average of 7.4, and this is perhaps due in part to the banking crisis of 2008 and associated economic decline. For the HPI, the ecological footprint data for all nations is taken from the WWF's living planet report. Although Iceland's EF has not been officially published by the WWF, the NEF have used a figure of 6.5 ha per capita [73]. As has been discussed in the EF section of this analysis, this figure is likely to be a considerable underestimate. If Iceland's actual EF of 12.7 ha per capita was used, the nation's HPI rating would be even lower than its current placing of 88th.

The HPI arrives at some surprising results that are not necessarily demonstrative of a direct relationship between subjective well-being and environmental strain. For instance, Costa Rica (HPI score of 64.0), the country sitting at the top of the ranking list, has experienced well-being and life expectancy broadly on a par with Icelandic performance, but its EF of 2.5 ha per capita is less than half the Nordic average [73]. The effect of the EF denominator on a country's eventual ranking is considerable. Of the top 10 nations, 9 are to be found in South America. None of these countries have performed particularly well economically over the course of the 20th Century, and few have had any long-term political stability. But the HPI does not attempt to glean causal data behind a particular standard of well-being. Overall the HPI results are suggestive that a small ecological footprint is incompatible with the necessary economic prosperity required to facilitate a generous welfare state, one that invests in healthcare, boosts life expectancies and contributes to human well-being. Of the top 40 countries in the HPI list, only Switzerland, Norway, New Zealand and Israel have a GDP per capita of greater than $15,000, and these four countries have the largest EF's out of this group and are the only nations boasting average life expectancies of greater than 80 years [73]. Thus the HPI is more illustrative of the competitive aspect between the three pillars of sustainable development, as opposed to demonstrating the level of environmental strain necessary to facilitate a certain standard of human well-being.

By weighting the ecological footprint denominator very highly, the HPI reinforces the impression that Iceland is living beyond its environmental boundaries, an observance that can be drawn separately from the EF index itself. Given that there are a myriad of variables that determine subjective human well-being outside of the environmental domain, the ecological footprint would

Table 5
Icelandic HPI performance and component analysis [73].

Country	HPI ranking	HPI score	Mean experienced well-being (score from 0 to 10)	Mean life expectancy (years)	Ecological footprint (global hectares per capita)
Iceland	88	40.2	6.9	81.8	6.5

appear to be the only issue of relevance to the environmental sustainability discussion that can be drawn from the HPI.

4. Discussion

This section revisits the research questions posed in the introduction to this paper, considering further issues in the light of the analysis of Iceland's environmental sustainability performance. The first question, (1) How to measure a country's environmental sustainability performance?, is discussed in Section 4.1. but we discuss the other two, (2) how environmentally sustainable is Iceland?; and (3) how can Iceland improve its environmental sustainability performance?, jointly in Section 4.2.

4.1. How to measure a country's environmental sustainability performance

This paper has used four environmental indices as tools to reveal Iceland's environmental sustainability characteristics. As a means of stimulating policy responses, the simplicity of the environmental indices leaves them too generic in quality and omitting important criteria. Similar weaknesses in sustainable development metrics were uncovered by van Zeijl-Rozema et al., whereby a lack of regional specifics was found to weaken the quality of ensuing analysis [74]. At a national level, this paper has also taken the perspective that environmental sustainability indices are currently a poor means of establishing a county's environmental sustainability performance on their own, and nationally specific issues always need to be reviewed and incorporated to ensure that an assessment is holistic and has validity as a means of stimulating policy-responses.

Even the most robust of the environmental sustainability indices, the EPI, lacks sufficient scope to fully evaluate Iceland's performance, ignoring the issues of soil degradation and waste management. Although a policy-to-target approach is utilised, its environmental health objectives tend to be focused upon issues only relevant to the developing world. In addition, data omissions abound, and much of what is used dates from 6 or 7 years ago, rendering the accuracy of the ranking list hard to verify. The EF indicator acts as a form of clarion call, a headline measure indicating whether a country is living beyond its productive means. However, it is predominantly a measure of consumption – analysing the question of how much, not examining the environmental impacts of development. Important issues such as the degradation of productive land resources or biodiversity loss are not encompassed within the EF metric. The HPI is perhaps the least robust of all of the indices, assuming a direct relationship between subjective human well-being and environmental strain via an ecological footprint calculation.

The use of a single environmental index is, on its own, too simplistic and deficient an approach to critically assess a country's environmental sustainability performance. Even the approach of analysing several indices together fails to uncover and synthesise all of the components needed to measure environmental sustainability in a national context. This paper sets out a holistic method for measuring a country's environmental sustainability performance using indices, whilst maintaining a degree of flexibility and broader awareness to ensure that all environmental components are integrated into the analysis. It is important to note that this approach is only sufficient to measure the environmental sustainability performance of a single country – despite the use of ranking lists via selected indices, the need for expert insight into a nation's environmental circumstances, renders this strategy ill-equipped to facilitate international comparisons overall. The environmental sustainability credentials of each and every country need to be established independently; however the use of common indicator pools for regions [74] and well-established indicator frameworks such as aspects of the EPI can be helpful when comparing some common issues.

It is conceivable that a holistic evaluation of a nation's environmental sustainability credentials could be further refined through the development and use of a 'synthetic' index, utilising core and satellite indicators, and then applying a suitable weighting system. In contrast to the EPI, which is generic to all nations and encourages policymakers to focus on comparative performance in ranking lists, a future synthetic environmental sustainability index (ESI) could serve as a form of flexible platform for application at solely the national tier of governance. The constituents of a national ESI might differ from one country to the next, although core indicators would be identical, covering a range of critical environmental sustainability topics that are common to all locations. Satellite indicators could then be drawn from common pools to embed national specificities into the index. An ESI could be structured to include the following six sub-indices: energy performance; waste management; air quality and pollution; water quality and pollution; land use intensity, agriculture and fisheries; and biodiversity, forests and soil degradation. It is not the role of this paper to fully articulate and verify a new ESI. However, it is possible to scope out a realistic set of 24 core indicators, drawn from the indices analysed in this paper and the common pool of European Union sustainable development indicators (EU SDI). Table 6 summarises a proposed core structure for the synthetic ESI.

All of these indicators lend themselves to the distance-to-target method of appraisal that the EPI adopts. The setting of specific indicator targets will need to be established by policymakers in tandem with advice gleaned from experts. In addition, the weighting system applied to the index and its constituent sub-indices will need to vary from nation to nation. The act of applying a weighting system to any environmental sustainability index is afflicted by varying degrees of subjectivity and arbitrariness. There will thus remain a considerable role for expert judgement in terms of determining the issues of greatest relevance to a nation's environmental sustainability performance, and, if required, choosing a small number of appropriate satellite indicators to supplement the core set. In order to ensure that a fair calculation methodology is established, a combination of expert views and focus group research might be the most appropriate means of arriving at a weighting system. The emphasis in this evaluative platform is one of flexibility and scope – even for core indicators, there remains the possibility of applying an indicator weighting of zero for criteria deemed to be irrelevant or unimportant, such as items relating to the marine environment for landlocked nations. Equally, expert judgement and analysis will be needed to review the economic patterns and trade-offs afflicting performance in the ESI, and offer policymakers the most realistic means of initiating future improvements.

In the future, this paper advocates the use of expert judgement to develop a synthetic ESI by (a) identifying the main national influences on environmental sustainability and comparing these to the core set of indicators in Table 6, (b) completing the holistic evaluation by incorporating relevant satellite indicators, (c) establishing appropriate indicator targets to measure progress against, and (d) uncovering an applicable weighting system based on robust public consultation.

4.2. How environmentally sustainable is Iceland and how can the country improve?

Iceland's performance within the selected environmental sustainability indices reveals a number of areas where the nation's

Table 6
Proposed synthetic ESI structure.

Sub-index category	Core indicators	Indicator source
Energy Performance	Total annual CO_2 emissions	EPI
	CO_2 emissions per unit of energy generated	EPI
	CO_2 emissions per unit of GDP	EPI
	Proportion of electricity generated from renewable sources	EU SDI
	Total annual primary energy consumption	EU SDI
	Energy independence	EU SDI
Waste management	Total volume of waste production	EVI
	Proportion of waste re-used and recycled	EVI
Air quality and pollution	SO_2 equivalent average annual emissions	EPI
	NO equivalent average annual emissions	EPI
	PM10 average annual emissions	EPI
	PM2.5 average annual emissions	EPI
Water quality and pollution	Proportion of collected wastewater that is treated	EPI
	Proportion of population with access to safe drinking water	EPI
	Annual water usage as percentage of 'renewable' water resources	EVI
	Surface and groundwater abstraction as a share of available drinking water resources	EU SDI
Land use intensity, agriculture and fisheries	Ecological footprint	EF/HPI
	Annual intensity of fertiliser use over the total land area	EVI
	Fish catches from stocks outside safe biological limits	EU SDI
Biodiversity, forests and soil degradation	Percentage of terrestrial habitats accorded protected status	EPI
	Percentage of the EEZ accorded protected status	EPI
	Percentage of total land area covered by forests	EVI/EPI
	Percentage of total land that is either severely or very severely degraded	EVI

policy-makers can potentially stimulate improvements. This paper now proceeds to describe a brief array of recommendations to improve Iceland's performance against the EPI and EF indices, in addition to offering further advice concerning measures that can be taken to advance environmental sustainability in the pertinent areas of soil degradation and waste management.

As the EVI relates to a one-off static assessment of specific national environmental vulnerabilities from 2005, there is little merit attached to setting out means of moving towards a better ranking. The final EVI list can bear little resemblance to the realities of the vulnerability of the environments, or indeed societal responses to these threats that have already been undertaken. Given these concerns, the EVI is a poor tool for advancing environmental policy-making.

Due to the uncertainty of the HPI as a measurement of human well-being relative to environmental strain, the only relevant component of its metric is the ecological footprint denominator, a statistic that is already solely the focus of the EF index.

Reducing Iceland's SO_2 equivalent emissions would improve the nation's performance under the EPI's environmental vitality objective. Icelandic regulations relating to air pollution follow from European Union Directives and recent domestic legislation that stipulates limiting values for H_2S in the ambient air. Under Icelandic law ratified in 2010, from July 2014 H_2S concentrations will be required to never exceed 50 $\mu g/m^3$ in Reykjavík. This is a precautionary standard, as the long-term health effects of exposure to low-level concentrations of H_2S are not known. It is evident that meeting this standard will require the adoption of wet scrubbing technology to Iceland's Hellisheiði geothermal power plant. Furthermore, in the absence of an installed solution at Hellisheiði, no further expansion in geothermal energy utilisation can currently be considered in the Reykjavík vicinity. Iceland is the only country in the Nordic region with abundant high temperature geothermal energy resources. Although generally classified as a renewable energy [75], the sustainable management of the geothermal resources is critical to the environmental sustainability of the country. Expansion in geothermal energy production has led to growth in SO_2 equivalent emissions, with a range of potential health implications for humans and the natural environment.

Although the EPI currently lacks actual data in relation to Iceland's PM 2.5 output, the nation's annual average PM 10 concentration are measured in Reykjavík and have been consistently above safe WHO guidelines. Thus far Iceland has not measured its PM 2.5 concentrations, however these measurements will be required if the European Union Directive on air quality becomes part of the European economic area agreement of which Iceland is a member. This directive requires countries to monitor and reduce PM 2.5 concentrations to below 20 $\mu g/m^3$ by 2015 and places minimum standards on polluting industries. Improving Iceland's performance in the EPI would require PM 2.5 concentrations to average less than 10 $\mu g/m^3$ per year in accordance with the WHO guidelines. Efforts to reduce particulate matter concentrations across Reykjavík need to be focused on the transportation sector, particularly reducing emissions of soot from engines, increasing asphalt durability and over the longer-term, the greater use of low emission cars.

The EPI highlights the over-exploitation of fish stocks as a concern, although the use of data from 2006 potentially gives an out-of-date perception of Iceland's performance. Recent assessments have indicated that although the recovery of overall stock levels is underway, fish stocks for trawled species, particularly cod, remain low [60]. Based on ITQs and strict regulations such as closed areas, mesh-sizes and selective fishing gear, the Icelandic management system limits the TAC, thus theoretically preventing more fishing from the stocks than is determined by scientists to be environmentally sustainable.

Reducing Iceland's EF requires focus on the consumptive pressures driving the Carbon Footprint. During the period up to 2008, imports of cars escalated; meanwhile the fishing fleet is responsible for over 15% of Iceland's CO_2 emissions, and thus the main environmental sustainability challenge facing these sectors is to gradually reduce fossil fuel consumption. Although per capita car ownership is the fifth highest in the world, some progress has already been made to reduce the environmental impact of the fleet, particularly via the utilisation of more energy efficient engines.

Taxes on low-polluting vehicles have been reduced, rendering diesel-powered and renewably-fuelled cars more economically competitive than before [76]. New and more energy efficient technologies have been successfully introduced to a number of ships [77], and further opportunities may be available in the coming years for Iceland to potentially utilise biofuels in cars and hydrogen fuel cells in large, long-haul trucks [76,78].

Commitments to afforestation and re-vegetation programmes are integrated into Iceland's climate change policy, where carbon sequestration is a key focus. The importance of soil reclamation and re-vegetation in Iceland relates to the future need for productive land resources, biodiversity preservation, soil and water conservation, and carbon sequestration as a measure to combat climate change and satisfy Kyoto targets for greenhouse gas emissions. Afforestation programmes in Iceland can fulfil a number of sustainable development objectives, not limited to the domain of environmental sustainability. Long-lasting economic (e.g. timber products) and social benefits (public health and recreational) can also be reaped. Afforestation is also a central background theme to the EF, and has particular relevance to Iceland's situation with 89% of the total EF comprised of ‘carbon offset from forests’. Approximately 95% of Iceland's total forest cover was lost in the post-settlement period, significantly reducing the potential absorptive capacity of the environment. CO_2 emissions from severely degraded land resources exacerbate the problem.

Goodland asserts that a pre-requisite of environmental sustainability involves a society ensuring that the sinks for human wastes and pollution are not exceeded [4]. Although waste management issues are not covered by the EPI, Iceland has an increased annual volume of total waste over the period 1995–2011, although 2008 represented the year of peak generation [66]. To advance environmental sustainability, there is a need for waste generation to be reduced as much as practicable and recycling rates to be increased beyond the current performance of 55.7% [66]. Approaches such as RR-SKIL for electronic waste, designed at decoupling the use of resources and waste generation and economic growth, accord with the second of the OECD's five inter-related objectives for the formulation of policies for environmental sustainability. A variety of initiatives could be adopted to progress this endeavour, including environmental incentives and enhanced information provision and education. Economic incentives based upon the ‘polluter pays principle’ have already been used in Iceland to some degree, with tax levies on a number of hazardous waste product categories and fees demanded for disposable beverage containers. Other economic options available could include the imposition of process charges on domestically produced goods and imports to cover the cost of recycling. This approach is grounded in ‘polluter pays principles’, and helps to cultivate an economic stimulus to reduce the amount of waste generated and the most efficient means of disposal.

Iceland's focus has been on using its seemingly abundant geothermal and hydro-power resources to generate electricity to serve aluminium plants. The environmental sustainability of renewable energy resources is determined not merely by their sustained yields and relatively low GHG emissions, but also their use and associated impacts. Over 46% of Iceland's total CO_2 emissions in 2010 were sourced from the metal production sector. The possibility of constraining CO_2 emissions from aluminium smelters in Iceland is small without changes in technology, although carbon-free anodes could be developed in the future and would present the option of producing low-emission aluminium. Due to the long-term (often 40 years) nature of energy contracts established in Iceland with aluminium corporations, decarbonising the industry itself appears to be the only means of improving Iceland's carbon footprint in the short to medium term.

5. Conclusion

Environmental indices, such as the EPI and EF, can act as a form of clarion call to national policy-makers, representing useful starting points when evaluating a country's environmental sustainability. This paper has demonstrated that it is possible to measure aspects of a country's environmental sustainability using selected environmental indices, but a full evaluation requires a holistic approach. Moreover, such indices and their ranking lists serve little purpose when endeavouring to compare how environmentally sustainable countries are.

The comprehensive and evaluative approach adopted in this paper provides a much more thorough analysis than a review of indices, and a myriad of nation-specific environmental issues are discussed. This paper thus presents an approach for measuring a country's environmental sustainability performance using indices, whilst maintaining a degree of flexibility and broader awareness to ensure that all environmental components are integrated into the analysis. Although the environmental sustainability credentials of each and every country need to be established independently, the use of common indicator pools for regions and well-established indicator frameworks, such as aspects of the EPI, can be helpful when comparing some common issues. The development of a synthetic and flexible ESI, capable of being applied to any nation, represents an important next research project and practical advancement of the evaluative approach taken here. In a synthetic ESI, some international performance comparisons may be feasible for core indicators, but the main aim would be purely a consideration of nationally specific environmental sustainability components and performance.

This paper has shown that Iceland's performance according to the ranking lists of environmental indices varies considerably. In order to examine why this is the case and provide the sought-after evaluation of a country's ‘true’ performance, this paper has examined the four selected indices together, and in the light of the special circumstances that pervade in the unique country of Iceland: exceptional renewable energy resources, a small but growing population, a sensitive and geographically isolated environment, and an economy reliant on heavy industry and its fishing industry. Although Iceland performs admirably according to generic environmental health objectives set out within the EPI and has advanced levels of renewable energy utilisation, the country has several weaknesses that scupper the country's overall environmental sustainability credentials. A very high carbon footprint (the main component of a very high EF relative to national biocapacity), led by imports, is apparent despite the widespread utilisation of abundant sources of renewable energy. Greenhouse gas emissions in Iceland derive from two main sources: industrial processes and fossil fuel combustion in cars and ships. The main threat to environmental sustainability in Iceland and human well-being concerns not what energy is used, but how it is applied – the expanded utilisation of geothermal energy reserves to serve aluminium production has led to increased emissions of hydrogen sulphide and particulate matter (particularly PM 10) in recent years in the Reykjavík area. Furthermore, the carbon and energy-intensive industrial process of aluminium production is the chief driver of increased carbon dioxide and overall greenhouse gas emissions in Iceland. Population growth, an expansion in car ownership and the reliance of the vehicular fleet on the combustion of fossil fuels have also placed upwards pressure on Iceland's CO_2 emissions and its EF.

There remain opportunities for Iceland to reduce greenhouse gas emissions from the transportation sector, particularly via a shift towards the use of lower-emission vehicles and ships. In the short-term, there are significant technological constraints preventing the aluminium industry from significantly reducing its current

level of carbon-intensity. Due to the long-term nature of energy contracts with aluminium producers in Iceland, policy-makers can more realistically target environmental sustainability performance improvements by continuing to enforce upcoming strict regulations for hydrogen sulphide emissions.

Land and soil degradation remains a major nationwide environmental challenge. Since Iceland was settled, approximately 96% of all forest and 60% of vegetative cover has been lost [79]. This has had two major implications – the capacity of the natural environment to sequester carbon from the atmosphere has been greatly diminished, and significant carbon dioxide emissions have occurred from overused land and drained wetlands. Given the recent growth in carbon dioxide emissions from industrial processes, there is an urgent need for further afforestation and re-vegetation programmes within Iceland, a process that most probably represents the greatest opportunity for the country to improve its environmental sustainability performance. Afforestation and re-vegetation programmes can secure a number of benefits which are not limited to the domain of environmental sustainability, from carbon sequestration to the creation of further recreational opportunities for Icelanders.

In addition, further environmental sustainability benefits can be gleaned in Iceland through the adoption of more effective waste management practices. The total volume of waste generation in Iceland remains very high. Although recycling rates and the proportion of waste diverted away from landfill sites have gone up, recyclable materials are exported by container ship to Europe, increasing transport-related emissions.

The ranking of countries in indices and their application to demonstrate environmental sustainability credentials is not useful. It is possible to glean a broad picture of strengths, weaknesses and potential improvements in the future. Aspects of the EF and EPI can be used to compare certain aspects of sustainability between countries and establish common benchmarks, but the application of generic international targets greatly weakens the national political relevance of such indices. Instead, a comprehensive evaluation of a nation's environmental sustainability performance currently demands the use of multiple indices and a broad awareness of other criteria that may not be considered at all by such metrics.

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